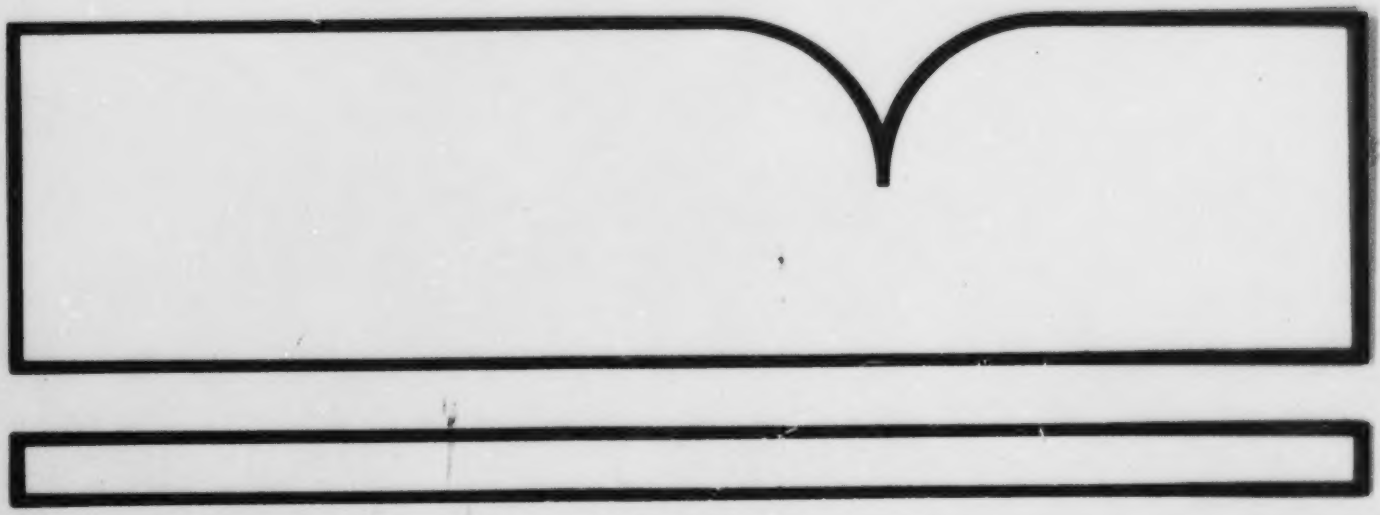
PB84-177344

Where Does Waterborne Giardiasis Occur, and Why

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

1984



U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-177344

EPA-600/D-84-100
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TECHNICAL REPORT DATA (Please read Instructions on the reverse before completing)		
1. REPORT NO. EPA-600/D-84-100	2.	3. RECIPIENT'S ACCESSION NO. PB84 127344
4. TITLE AND SUBTITLE Where Does Waterborne Giardiasis Occur, and Why?		5. REPORT DATE 1984
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Edwin C. Lippy and Gary S. Logsdon		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Health Effects Research Laboratory - Cinti., OH Municipal Environmental Research Laboratory - Cinti, OH Office of Research & Development U.S. Environmental Protection Agency, Cinti, OH 45268		10. PROGRAM ELEMENT NO. BNC1A 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Health Effects Research Laboratory - Cinti, OH Municipal Environmental Research Laboratory - Cinti, OH Office of Research & Development U.S. Environmental Protection Agency, Cincinnati, OH45268		13. TYPE OF REPORT AND PERIOD COVERED Conference Proceedings 14. SPONSORING AGENCY CODE EPA/600/11 EPA/600/14
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Over 60 outbreaks of waterborne giardiasis occurred in the United States between 1965 and 1982, mainly in the Northeast, the Rocky Mountain states, and the Pacific states. Outbreaks most often occurred as a result of inadequate or interrupted treatment. Disinfection problems and failure to provide filtration treatment were noted in a majority of treatment-related outbreaks. Inadequate coagulation and poor filtration practices were identified as problems where treatment was provided. Recent research has shown the sort of treatment practices that can permit Giardia cysts to pass through treatment plants as well as what is needed to provide effective barriers to the cysts.

17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 11
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

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Where Does Waterborne Giardiasis Occur, and Why?

Edwin C. Lippy* and Gary S. Logsdon†

Abstract

Over 60 outbreaks of waterborne giardiasis occurred in the United States between 1965 and 1982, mainly in the Northeast, the Rocky Mountain states, and the Pacific states. Outbreaks most often occurred as a result of inadequate or interrupted treatment. Disinfection problems and failure to provide filtration were noted in a majority of treatment-related outbreaks. Inadequate coagulation and poor filtration practices were identified as problems where treatment was provided. Recent research has shown the sort of treatment practices that can permit Giardia cysts to pass through treatment plants as well as what is needed to provide effective barriers to the cysts.

Introduction

Giardia lamblia, the causative agent of giardiasis, is a protozoan that infects the intestinal tract of man. It is the pathogen most often identified in waterborne disease outbreaks. The agent survives in the environment in its cyst stage and when ingested excysts to its reproductive stage as a trophozoite. The trophozoite causes the illness. As it passes through the lower intestinal tract, the trophozoite encysts and is discharged from the body. Giardia cysts can survive in the aquatic environment, especially in cold lakes or streams, for months, and are more resistant to disinfection than most other microbial pathogenic agents. Data for the figures and tables in this document were obtained from "Centers for Disease Control: Water Related Disease Outbreaks, Annual Summary," using summaries for the years 1965 to 1982.

Distribution of Outbreaks

The first reported outbreak of waterborne giardiasis occurred in 1965 in Aspen, Colorado. Since that first event, 62 additional outbreaks have occurred in the past 17 years. The trend in giardiasis outbreaks is increasing, as shown in Table 1. Whereas total outbreaks from giardiasis and all other waterborne diseases are increasing steadily with about forty more in each five-year increment, giardiasis outbreaks are rapidly increasing, with the number doubling every five years.

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The temporal distribution of giardiasis outbreaks shown in Fig. 1 indicates a substantial difference in the pattern for community vs. non-community systems. No clear seasonal trend occurs for outbreaks in community systems. While an increase is noted in the summer months in Fig. 1 for non-community water systems (campgrounds, parks, other facilities serving travelers and vacationers), the absence of outbreaks in these same systems during fall and winter months is more notable. Use of these facilities is seasonal with the summer months attracting heavy visitation. During the winter months campgrounds and parks are closed or operate at much reduced visitor loadings resulting in less stress placed upon the water system. This apparently results in fewer giardiasis outbreaks.

Geographic distribution of giardiasis outbreaks is shown in Fig. 2. Areas having the most outbreaks are located in the northeast from Pennsylvania to New Hampshire and in the Rocky Mountain and Pacific states. Many water systems in these areas use mountain streams and lakes as a source of supply. Because of good quality water and absence of point-source wastewater discharges in the watershed, many systems provide minimal treatment -- often chlorination only. They are required to comply with the National Interim Primary Drinking Water Regulations which specify limits for coliform bacteria. Chlorination that is provided in these situations can be effective in destroying the coliform organism, but is not necessarily effective for inactivating giardia cysts.

Deficiencies Associated with Outbreaks

Table 2 shows public water system deficiencies that cause and contribute to giardiasis outbreaks. The first two categories involve water systems with neither filtration nor disinfection. Category 3, inadequate or interrupted treatment, is defined as breakdowns or defects in existing treatment processes that permit inadequately treated water to be distributed. Category 4, deficiencies in the distribution network, includes events that cause contamination through cross-connections, ruptured mains, open reservoirs, etc. Category 5 includes causes not included in the other four categories and outbreaks not investigated to the extent that a cause was determined.

Table 2 shows that two-thirds of the giardiasis outbreaks were related to failure to provide adequate or reliable treatment (category 3). This category was further subdivided to highlight treatment deficiencies as shown in Table 3. Chlorination deficiencies were a primary cause in a large majority of the outbreaks, with failure to filter a secondary cause, while clarification deficiencies (coagulation, settling, filtration) were the primary cause in about one fifth of the outbreaks.

Some common problems with chlorination that contribute to outbreaks are over-dependence on indicator organisms to assess the adequacy of disinfection, failure to apply currently available technology, and overestimation of the effectiveness of disinfection practice.

A positive coliform sample means that coliform bacteria are present and it may mean that pathogens are also present. A negative sample

indicates the absence of coliform bacteria but does not indicate the absolute absence of pathogens not detected by the coliform test. Pathogens more resistant to disinfection than coliforms, including cysts and viruses, may be present. Where water systems may be challenged by Giardia cysts, reliance should not be placed totally upon meeting the coliform maximum contaminant level (MCL), but should also include effective treatment measures.

To be effective in inactivating Giardia cysts, chlorination must be practiced accounting for pH, contact time, temperature and turbidity. Chlorine must be added in response to plant output, and the facilities should be reliable to the extent that the process is not interrupted.

The pH of the water being chlorinated is extremely important. It determines the percentage of hypochlorous acid and hypochlorite ion in solution. At low pH the hypochlorous acid form is predominant, while at the higher pH hypochlorite ion is predominant. Hypochlorous acid is the more effective disinfectant. Some water utilities may raise pH to control corrosion, thereby reducing chlorination efficiency. This practice must be evaluated where a cysticidal chlorine residual is necessary.

Temperature must also be taken in to consideration, as chemical reactions progress more rapidly in warm water as opposed to slower reactions in cold water. Sufficient contact time is necessary to allow chlorine to function effectively. The effect of low temperature on disinfection can be a factor for several months or longer each year in northern latitudes and at the high elevations of some water supplies in the Rocky Mountains, where temperatures in the range of 0° C to 5°C are common.

Disinfectant contact basins need to be designed to promote plug flow rather than the mixed flow that too frequently occurs in contact basins and sedimentation basins. Concerning the latter, Gemmell stated in Water Quality and Treatment, "Detention time must be distinguished from the 'flowingthrough time,' the minimum time required for a particle of water to pass through the basin. The detention period may vary from nearly one to twenty times the flowing-through period, depending on the shape and dimensions of the basin, the design of the inlet and outlet structures and baffles, and other factors that affect the degree of short-circuiting that occurs in the basin" (4). These principles also are applicable to tanks used as chlorine contact basins. The actual flow-through time, rather than theoretical time, should be considered when the product of contact time and disinfectant concentration is calculated. Use of theoretical detention time to calculate disinfection requirements could result in underestimating the disinfectant dose.

Reliability in the disinfection process should encompass those factors that assure continuous uninterrupted and adequate disinfection. The demand for water fluctuates, so constant rate feeders that are paced to dose for an average output will be underfeeding during peak hours and overfeeding during low demand hours. Facilities that feed disinfectant should be capable of responding to changes in plant output.

Reliability in chlorination at small plants also requires two cylinders yoked up to the chlorinator so that when one cyliner is depleted of gas another can be put into use without interruption of chlorine feed. Current technology provides for automatic switchover from the depleted to the charged cylinder. Automated monitoring devices are available to give continuous readout of chlorine residuals and are a desirable feature. Auxiliary power should be provided so that chlorine feed is not interrupted by a power failure. Emergency power generation facilities with automatic start up are available and should be incorporated in the chlorination facility.

Even though chlorination can inactivate over 99.9 percent of Giardia cysts under proper conditions, filtration of surface waters is also needed to provide multiple barriers to the passage of cysts. Filtration of surface waters is supported by the American Water Works Association (2). Of the giardiasis outbreaks in public water systems associated with chlorination deficiencies, only a small fraction of the systems provided filtration. Seven outbreaks involved failures of both clarification and chlorination.

Effectively operated filters can provide a barrier to the passage of cysts, but rapid rate sand, dual media, or mixed media filters are sometimes operated with no coagulation when the source water meets the 1 NTU Maximum Contaminant Level for turbidity. This improper practice does little more than strain water and cannot be depended upon for consistent removal of Giardia cysts (3, 7, 8). Research results indicate that coagulated waters that are filtered to attain 0.1 NTU in the filtrate will show a substantial reduction in cyst concentration (7). The American Water Works Association set 0.1 NTU as a quality goal for potable water, and stated, "Improved technology in the modern treatment processes make this a completely practical goal" (1). Other factors that have been shown experimentally to permit passage of substantial numbers of cysts through filters include coagulation at a pH that is improper (3), use of inadequate coagulant dose (3, 7, 8), allowing turbidity breakthrough to occur at the end of a filter run (8), and causing sudden increases in the filtration rate (8). The above-normal turbidity observed during the ripening phase at the beginning of a filter run has been associated with the passage of cysts by an experimental rapid rate filter (8).

A number of problems have been identified at plants involved with giardiasis outbreaks. These include filtering uncoagulated water (6) and filtering inadequately coagulated water and operating at an inappropriate pH value (5). In two plants with rapid rate pressure filters, problems with loss of media (5) and mounding of media (5, 6) were noted. Also, inadequate backwash resulted in agglomerated mud masses in the filter media at one plant with pressure filters (6). Improper construction permitting some unfiltered water to mix with filtered water was noted (6).

Conclusions

- The number of waterborne giardiasis outbreaks is increasing.

- Treatment problems most frequently noted in outbreaks are related to disinfection inadequacies and failure to provide filtration.

- A number of design and operating problems have hindered the efficacy of clarification processes (coagulation, filtration) at filtration plants associated with giardiasis outbreaks.

Appendix - References

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Table 1

Number of Waterborne Disease Outbreaks, 1963 to 1982

Time Interval	Giardiasis	All Others	Total
1963 - 1967	1	57	58
1968 - 1972	6	94	100
1973 - 1977	17	124	141
1978 - 1982	39	157	196

Table 2

Deficiencies Associated with Giardiasis Outbreaks in Public Water Systems, 1963 to 1982

Category - Deficiency	Percentage
1 - Use of untreated surface water	10.5%
2 - Use of untreated ground water	12.3%
3 - Inadequate or interrupted treatment	66.7%
4 - Deficiencies in distribution network	5.3%
5 - Miscellaneous or unknown	5.3%

Table 3

Treatment Problems Associated with Waterborne Giardiasis Outbreaks in Public Water Systems, 1963 to 1982

Problem	Number of Times Noted*
Chlorination inoperative	3
Chlorination inadequate	13
Chlorination adequacy unknown	14
Coagulation deficient	5
Filtration deficient	4

*More than one problem may have been noted at a given location.

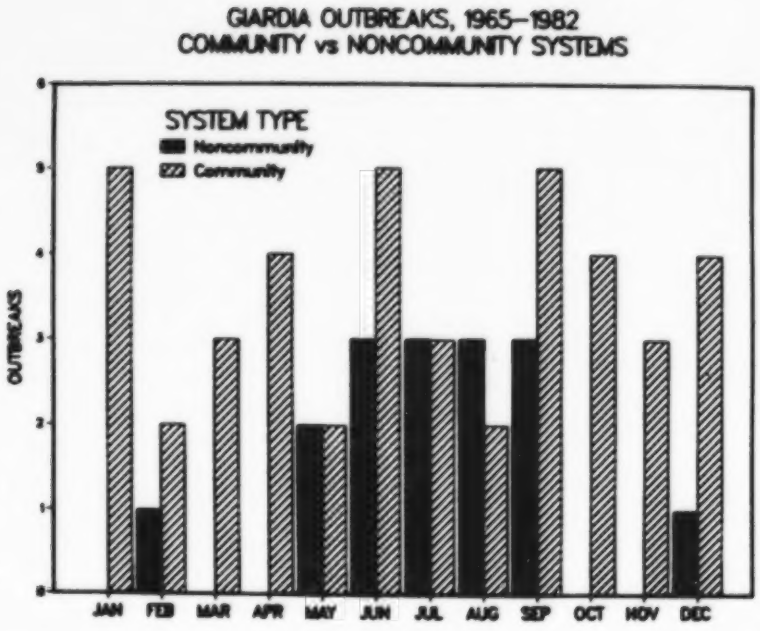

Figure 1

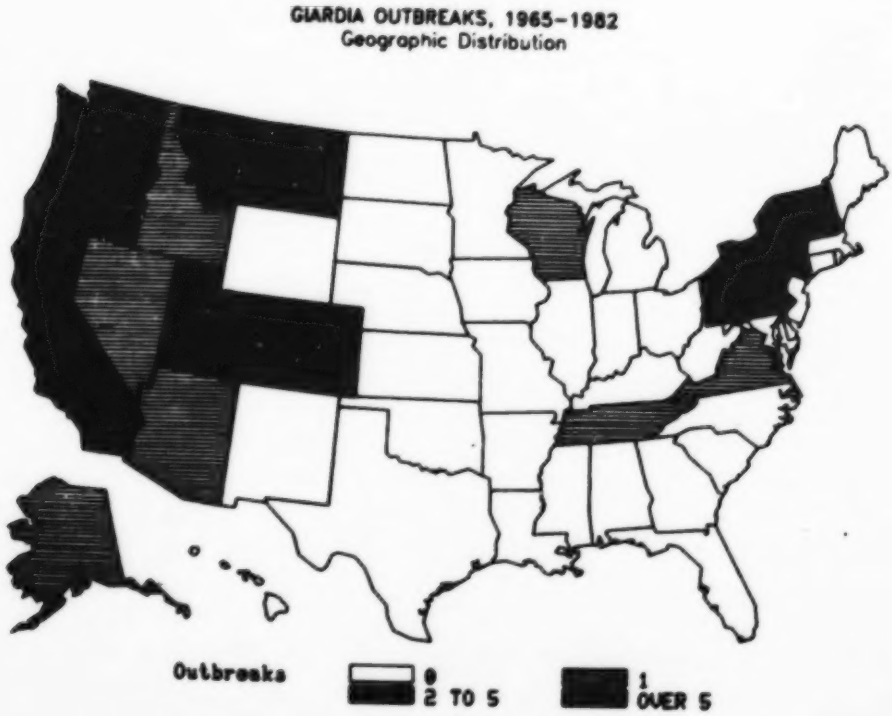

Figure 2